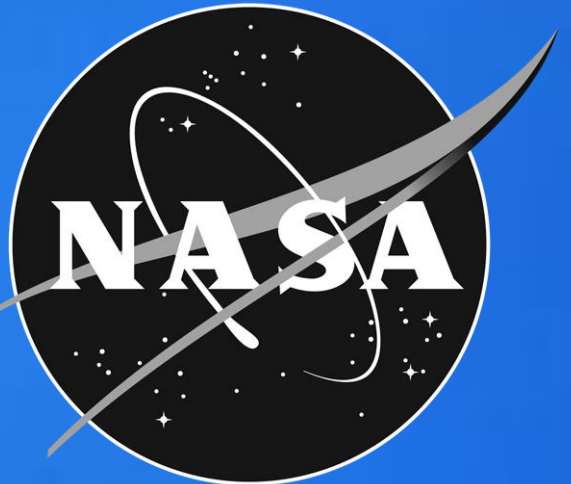


Turbine Engine Performance Estimation Using Particle Filters

Bong-Jun Yang, Prasenjit Sengupta, P. K. Menon
Optimal Synthesis Inc.

National Aeronautics and
Space Administration



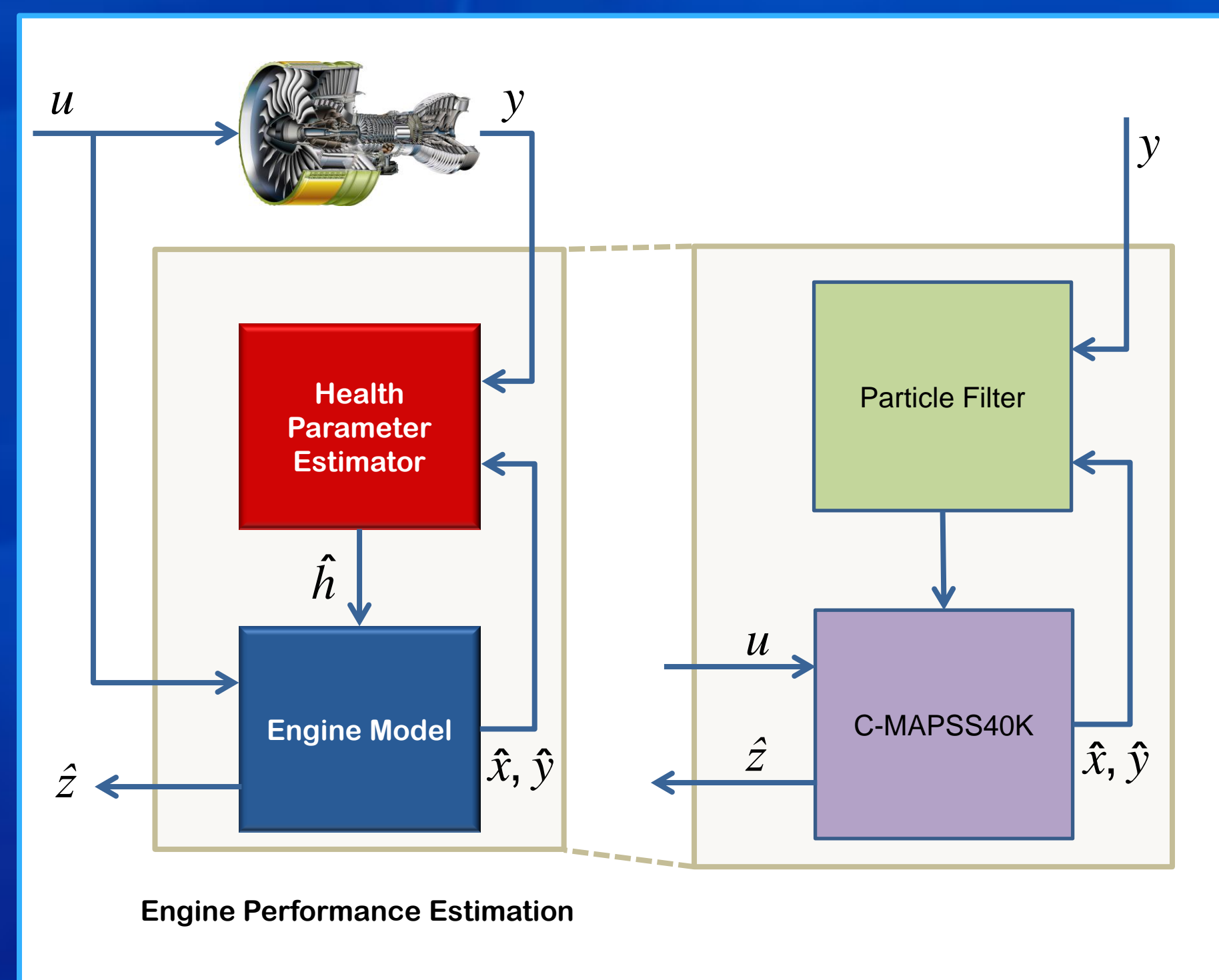
Description

The present research developed a nonlinear, non-Gaussian Particle Filter for engine health parameter estimation. The algorithm employs the NASA C-MAPSS40K engine model as its central element to overcome the limitations imposed by the Kalman filter.

Research shows that the Particle Filter can exploit the engine nonlinearities to enhance the observability of the system parameters.

Benefits

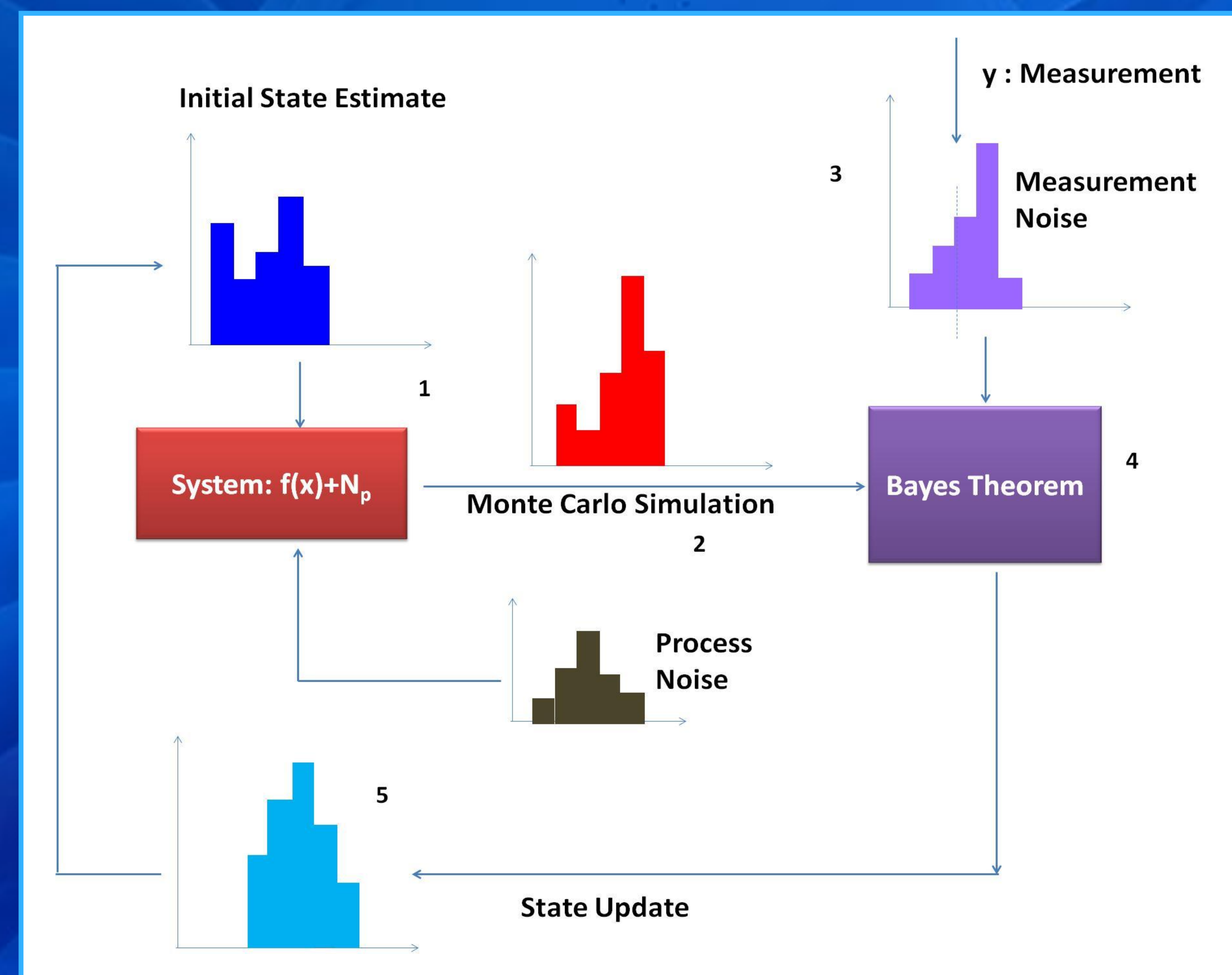
Engine parameter estimates can be used for health management, performance trend monitoring and gas path fault diagnostics. Accurate assessment of performance deterioration also allows for improved engine prognostics and condition-based maintenance.



Approach

A central feature of the present estimation problem is that the number of engine health parameters to be estimated are larger than available sensor measurements. This renders the linearized system partially unobservable. Based on an analysis of the high-fidelity NASA C-MAPSS40K model, the present research shows that the system is fully observable in a nonlinear sense. It also shows that the system observability can be enhanced by using specific inputs. A nonlinear, non-Gaussian 12-state particle filter is developed for the engine state-parameter estimation. The use of nonlinear dynamics in the estimation algorithm ameliorates the limitations imposed by Kalman filters.

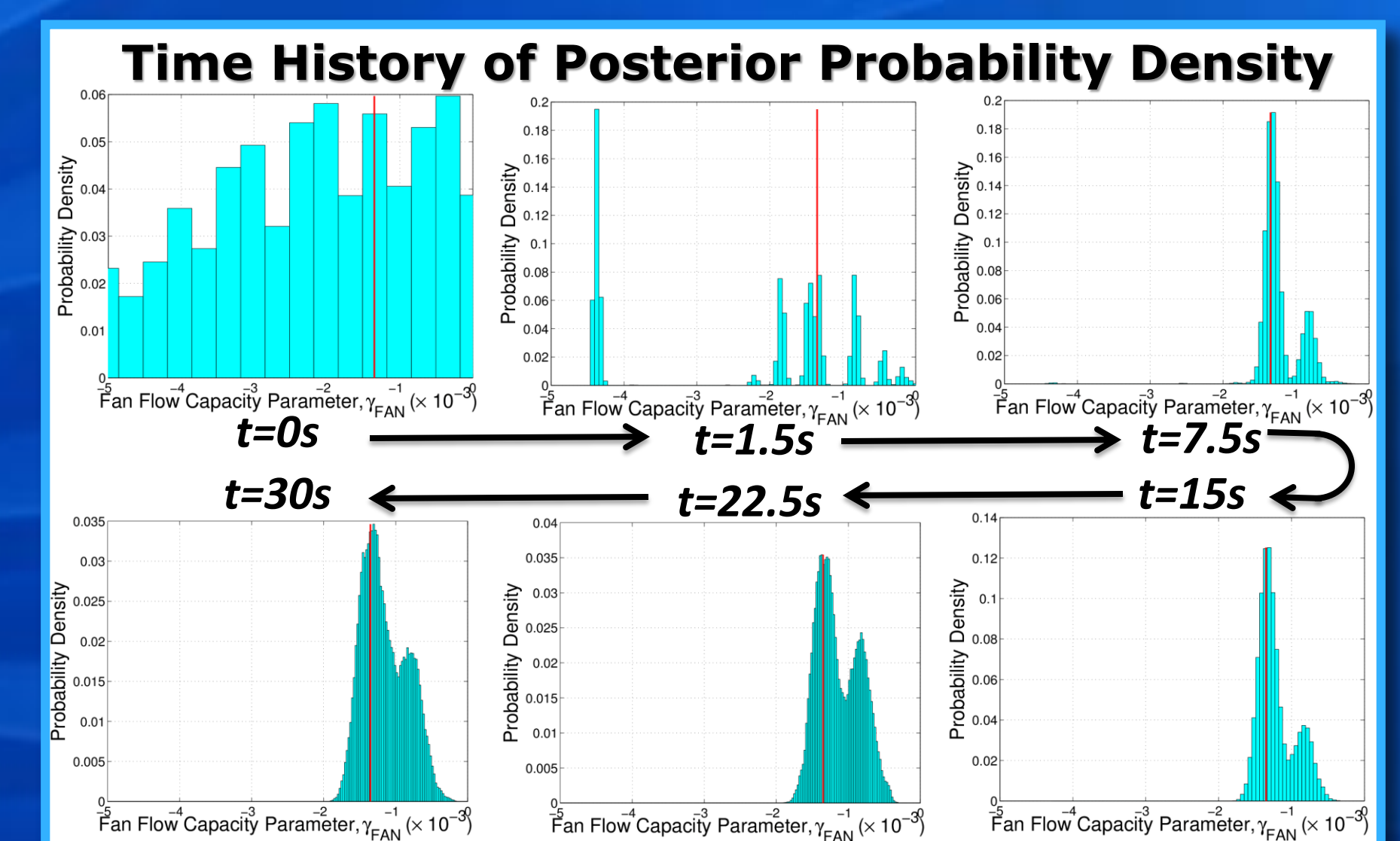
Parallel processing algorithm on a Graphical Processing Unit is employed to handle the massive computational requirements of the particle filter implementation.



Recent Results

- C-MAPSS40K engine model with 2 states and 10 health parameters are nonlinearly observable, while the linearized system is only partially observable.
- It is shown that particle filters can estimate additional health parameters when compared with the Kalman filter, using the same number of measurements.

An example time history of the posterior probability density from the particle filter reveals the non-Gaussian nature of the estimates.



Future Work

- Extension of the particle filter estimator over the entire operational regime of the engine, using more realistic noise models.
- Assessment of the sensitivity of the nonlinear observability test to individual health parameters.
- Particle Filter design for robust performance in the presence of modeling errors.
- Code optimization for faster execution.

